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Effects of Speech Signal Type and Attention on Acceptable Noise Level in Elderly, Hearing-Impaired Listeners

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Effects of Speech Signal Type and Attention on Acceptable Noise Level in Elderly, Hearing-Impaired Listeners

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Dedication

To my daughter, Katie, who has endured six long years with a tired and sometimes unavailable mother. Thank you for growing up a responsible, well-grounded and delightful young woman in spite of it.

To my late mother, Kitty Mundorff, who taught me how to persevere and to my father, Jack Mundorff, who believes I can do anything I "set my mind to do".

To my sister, Gretchen, who brings out my best by raising her bar higher and higher.

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Special thanks to the patients of The Better Hearing Center for their willingness to participate and to the Rockbridge Free Clinic for their help in acquiring participants.

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Abstract

The primary objective of this study was to determine if acceptable noise levels (ANLs) in elderly, hearing-impaired listeners were dependent on speech intelligibility and listener attention levels. Acceptable noise levels (ANLs), expressed in decibels, is defined as the maximum background noise level that is acceptable while listening to and following a story. Connected speech test (CST) sentences were recorded with clear speech, conversational speech and temporally altered, fast-rate speech. Thirty-five, elderly, hearing-impaired individuals (61-97 years, *M*=75) with symmetrical, bilateral sensorineural hearing loss participated. Most comfortable listening levels (MCL) and background noise level (BNL) measurements were completed for each speech stimulus under conditions of attention and non-attention. ANLs were calculated and results were compared to a previous, similar study with younger, normal-hearing individuals. A significant main effect of stimulus type was found suggesting that ANL is dependent on the intelligibility of the target speech signal. Although a significant main effect of attention was not reached, a significant interaction between attention and stimulus type was found showing the condition of attention to produce lower mean ANLs for clear speech and higher ANLs for fast-rate speech. In comparison to the younger, normal-hearing group, the participants in this study had higher ANLs, overall. These findings are contradictory to previous findings. Knowledge of these results may guide clinical audiologists in counseling patients and family members on communication strategies.

Chapter 1: Manuscript

Introduction

Understanding conversation in the presence of background noise is a significant problem for the hearing impaired. For those who wear hearing aids, many are unsuccessful, reporting that the hearing aids amplify the background noise to an intolerable level (e..g. Ries, 1998; Nabelek et al, 1991; Kochkin, 2002b). In recent years, audiologists have incorporated speech perception in noise tests to measure the hearing impaired patient's ability to communicate in the noisy, real world. However, speech perception measures have failed to give an accurate prediction of hearing aid success (e.g. Nabelek et al, 2006; Nabelek et al, 1991). Nabelek et al (1991) hypothesized that the acceptance of background noise may be more indicative of successful hearing aid use than speech perception in noise. The Acceptable Noise Level (ANL) measure, defined as the difference between an individual's most comfortable listening level (MCL) and the highest acceptable background noise level (BNL) proved to be an accurate predictor of successful use of hearing aids (e.g. Nabelek et al, 1991; Nabelek et al, 2006; Freyaldenhoven et al, 2006).

Research has shown that ANL remains reliable over time and is not affected by gender, hearing sensitivity or age (e.g. Freyadenhoven et al, 2007; Nabelek et al, 2004; Rogers et al, 2003; Crowley & Nabelek, 1996). Additionally, the type of background noise has not proven to affect an individual's ANL. (e.g. Nabelek et al, 1991). Speech presentation level has been shown to affect ANL causing an increase in ANL with an increase in presentation level (e.g. Franklin et al, 2006; Freyaldenhoven et al, 2006; Tampas & Harkrider, 2006).

Another factor that may affect ANL is the intelligibility of the target speech signal (e.g. Gordon-Hickey & Moore, 2008; Goldman, 2009). Studies have found that degraded or unfamiliar speech signals resulted in higher ANLs in normal hearing adults. Goldman (2009) studied the effects of using clear speech, conversational speech and temporally altered (rapid) speech on ANL scores of normal hearing listeners. This study was performed under the two conditions consisting of the participant attending carefully to the signal and the participant not really attending to the signal. Compared to mean ANL scores for conversational speech, normal listeners had lower ANL scores when the speech target was presented with clear speech and higher ANL scores with the fast rate speech presentation. Level of attention was found to have no significant effect on ANL scores (Goldman, 2009).

Clear speech, which is produced by reducing speech rate, exaggerating articulation and extending voicing (Krause & Braida, 2002) has been shown to be more intelligible to the hearing impaired (e.g. Picheny & Braida, 1989; Picheny & Braida, 1985; Krause & Braida, 2002; Caissie et al, 2005). Speech that is temporally altered causes difficulty in understanding in all listeners, but the effect is more pronounced in the hearing impaired and elderly (e.g. Tun, 1998; Gordon-Salant & Fitzgibbons, 1993). Under conditions of background noise and time compressed speech, the listener is presented with degraded sensory input paired with an increase in cognitive load resulting in additional effort to process the speech signal (Larsby et al, 2008).

Age-related difficulties in understanding temporally altered speech could arise as a consequence of temporal processing deficits associated with peripheral hearing loss, central timing issues and cognitive capacities (e.g. Gordon-Salant & Fitzgibbons, 1993;

Grose & Mamo, 2010; Hallgren et al, 2001b; Larsby et al, 2008). If the signal is limited due to background noise or temporal alteration, the listener has to compensate by depending on cognitive abilities to interpret and store information (e.g. Moore, 1996; Hallgren et al, 2001a). This skill is automatic, fast and accurate in the young, normal hearing adult, but becomes slower, controlled and inaccurate in the elderly or hearing impaired (e.g. Grose & Mamo, 2010; Larsby et al, 2008).

The aim of this study was to investigate background noise tolerance in the elderly, hearing impaired. For this purpose, ANLs were measured when the speech stimulus was presented with conversational speech, clear speech and fast-rate speech. Differences in ANL with varying speech stimuli were investigated. The secondary purpose was to determine the effect of attention level on ANLs. In addition, between-subjects factors of gender and hearing aid use were also examined. Three main research questions were asked: (1) Does changing the speaking rate of the target speech stimuli affect the ANL scores of the elderly, hearing-impaired listener? (2) Does the level of attention of the elderly, hearing impaired individual affect the amount of noise tolerated? (3) How do these responses compare to that of younger, normal hearing listeners?

Methods

Participants

Thirty-five participants, 21 males and 14 females, between the ages of 61 and 97 (M=75), were included in the present study. Of the 35 participants, 23 were hearing aid users (13 males, 10 females) and 12 did not wear hearing aids (8 males, 4 females). All participants had bilateral, sensorineural hearing loss with mean hearing threshold levels (HTLs) ranging from 36dBHL at 250Hz, sloping to 75dBHL at 8000Hz. Figure 1 shows means and standard deviations of hearing threshold levels (right and left ears) for all participants. Of the 35 participants, 23 (13male, 10 female) were long-term hearing aid users and 12 (8 male, 4 female) had never worn hearing aids. Regardless of hearing aid use, all experimental trials were conducted unaided. All participants were native speakers of American English and did not have an active speech and language disorder or neurologic disorder. Prior to testing, all participants underwent otoscopy and tympanometry to rule out outer or middle ear pathology. Participants were recruited from the patient population of The Better Hearing Center in Lexington, VA and employees and volunteers of the Rockbridge Free Clinic. In addition, several participants responded to a newspaper article regarding the study in the Lexington Gazette. All participants signed a statement of informed consent approved by the Institutional Review Board of James Madison University.

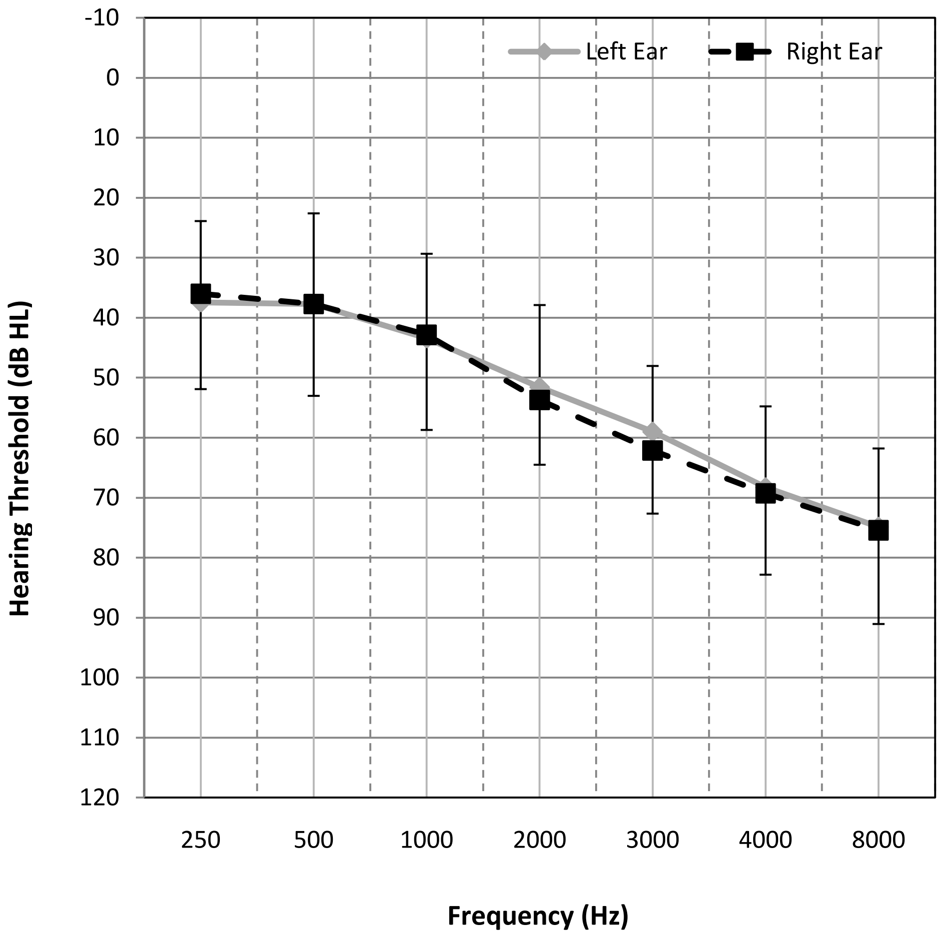

Figure 1: Mean HTLs for right and left ears of each participant (n=35). Error bars represent ± 1 standard deviation.

Stimuli

Using the Connected Speech Test (CST), three experimental conditions were created to produce clear speech, conversational speech and fast-rate speech. A professional radio announcer was instructed to record eight passages with conversational speech and 4 passages with clear speech. The instructions for clear speech which were given to the speaker are found in appendix A. Four of the conversational speech passages were then digitally altered to create speech passages that were 1.5 times faster to serve as the fast-rate speech stimuli. Multi-talker babble was selected as the only competing background noise signal because previous studies (e.g. Crowley & Nabelek, 1996; Lytle, 1994; Nabelek et al., 1991) revealed that other types of noises did not produce significantly different ANLs.

The background noise and spoken passages were recorded as stereo audio tracks on a compact disc. The first track on the disc was a 1000Hz calibration tone equated to the RMS value of the background noise and speech. The sentences used in each condition are listed in Appendix B.

Procedure

Preliminary procedures included obtaining informed consent, otoscopy and a behavioral audiometric evaluation. A copy of the informed consent is found in Appendix C. Testing was conducted in a single-walled, sound treated booth that met specifications for maximum allowable ambient noise levels (ANSI, 1999). The audiometric testing was performed using a Grason-Stadler Incorporated (GSI-16) audiometer and E-A-RTONE 3A insert earphones calibrated according to ANSI specifications for audiometers (ANSI, 1996). The speech stimuli were played through a Sony 6-disc CD player and were routed through the GSI 16 audiometer to a single loudspeaker mounted 1.5 meters from the participant at 0 degrees azimuth.

Prior to data collection, the participants were given oral instructions for each procedure (Appendix D). First, the participant's MCL was determined using a bracketing approach with spondee words via monitored live voice in varying intensity levels using 1dB steps. In order to test the reliability of the response, this procedure was repeated, with the MCL value of the second trial used to calculate ANL. To obtain ANL for the three different target speech signals, clear, conversational and fast-rate, the speech passages were delivered to the loudspeaker through channel B of the audiometer at the listener's MCL, while the speech babble was delivered through Channel A at 25dB below MCL. The speech babble was then gradually increased in 1dB increments until the listener signaled that an acceptable BNL has been reached. The BNL was described as a maximum level of the background noise to which the participant would be willing to accept without becoming tense and tired while listening to and following the words of the story. All participants were given the non-attending task first for which they were told that the comprehension of the speech passage would not be tested. After establishing an ANL for each target speech stimuli in the non-attending condition, the procedure was repeated for the attending condition. For the attending condition, participants were instructed to follow the details of the passages closely in order to be able to answer questions regarding the content of the passages when the listening task was finished.

In order to minimize the likelihood of practice and fatigue effects, presentation of the different speech stimuli was counterbalanced as was the two different sets of passages for each speech stimulus used for either the non-attending or attending condition

Results

Descriptive statistical data show the mean MCL of the 35 participants was 68.60 dB (SD=6.93), with a range of 52-82. Overall ANLs ranged from -5 dB to 14 dB.

Fast-rate speech produced the highest (poorest) ANLs in both the attending and non-attending conditions and clear speech produced the lowest (best) mean ANL scores for both conditions of attention. When comparing ANLs from the two conditions of attention, clear speech produced a lower (better) mean ANL in the attending condition (M=2.14 dB, SD=3.87) than that of the non-attending condition (M=3.29 dB, SD=3.87). Conversely, fast-rate speech produced a higher (worse) mean ANL in the attending condition (M=6.23 dB, SD=3.47) than that of the non-attending condition (M=4.74 dB, SD=3.33). Differences in ANL scores between the two conditions of attention for conversational speech were not as noticeable, with a mean of 3.46 dB (SD=2.72) for the attending condition and a mean of 3.60 dB (SD=3.25) for the non-attending condition.

ANLs recorded in the present study were higher than those found in the previous study with younger, normal hearing listeners. In the condition of non-attention, the previous study revealed ANL means of -3.00 dB (SD=5.44) for clear speech, -0.37 dB (SD=6.32) for conversational speech and 1.23 dB (SD=6.28) for fast rate speech. The younger, normal-hearing group had similar ANLs for the attending condition, with ANL means of -2.33 dB (SD=6.51) for clear, -0.37 dB (SD=5.53) for conversational and 1.77 dB (SD=5.56) for fast rate speech. These ANLs show more noise acceptance than those recorded from this study with older, hearing impaired individuals.

The mean values of ANL for the three stimulus types (clear, conversational and fast rate speech) under the two conditions of attention and non-attention, are illustrated in figure 3. Data analyzed by repeated measures with ANOVA revealed a strong main effect for stimulus type (f[2,62]=37.745, p=.000). As shown in figure 3, significantly lower ANL scores were recorded for clear speech and significantly higher ANLs were recorded for fast-rate speech. Pair wise comparisons showed significant results (α=.05, p=.000) for clear vs. fast rate and conversational vs. fast rate. Clear vs. conversational speech yielded near significant findings (α=.05, p=.053).

In agreement with Goldman's study on young, normal-hearing listeners, the present study revealed no significant main effect of condition of attention. However, a significant interaction of stimulus type x condition of attention (f [1,31]=17.370, p=.000) was observed. As shown in figure 2, when comparing the attending to the non-attending conditions, the elderly, HI participants had lower ANLs for the clear speech stimulus in the attending condition, but higher ANLS for the fast rate stimulus in the attending condition. The conversational speech stimulus yielded similar ANLs in the attending and non-attending conditions.

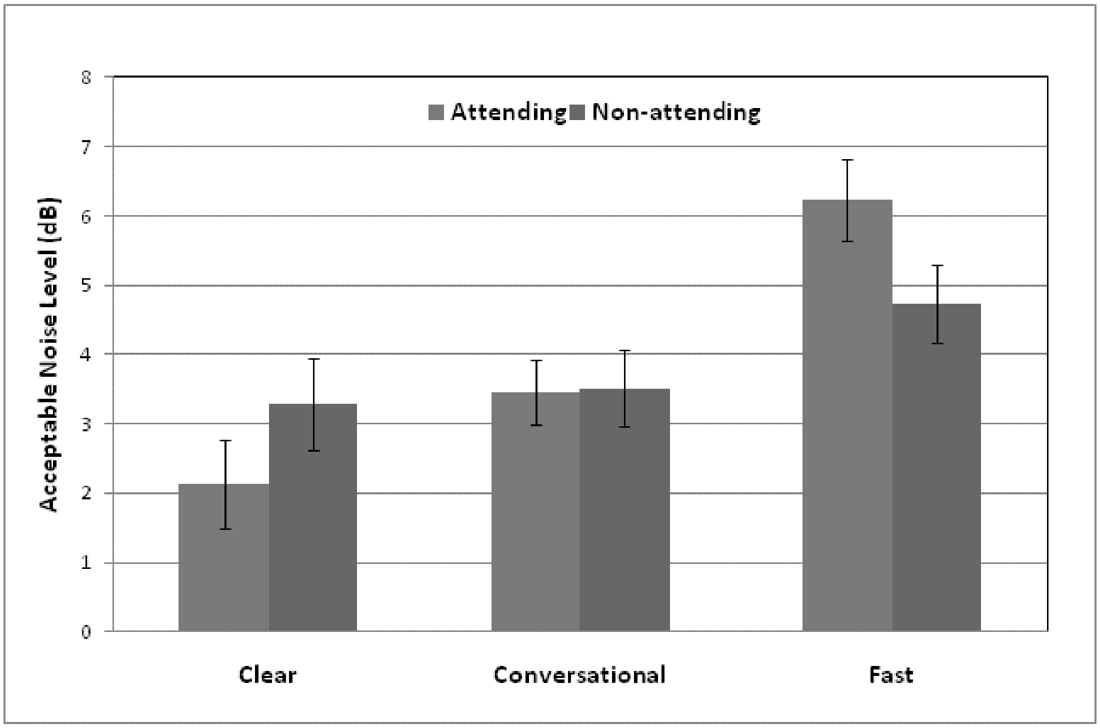

Figure 2: Mean ANLs and standard error for both conditions of attention across the three different speech stimulus types. Low ANL scores represent better tolerance to background noise than high ANL scores.

No significant main effects were found in the between subject factors of hearing aid user/non-user or gender. As shown in figure 3, there was no significant difference in the ANL scores of hearing aid users and non-hearing aid users, in either condition of attention.

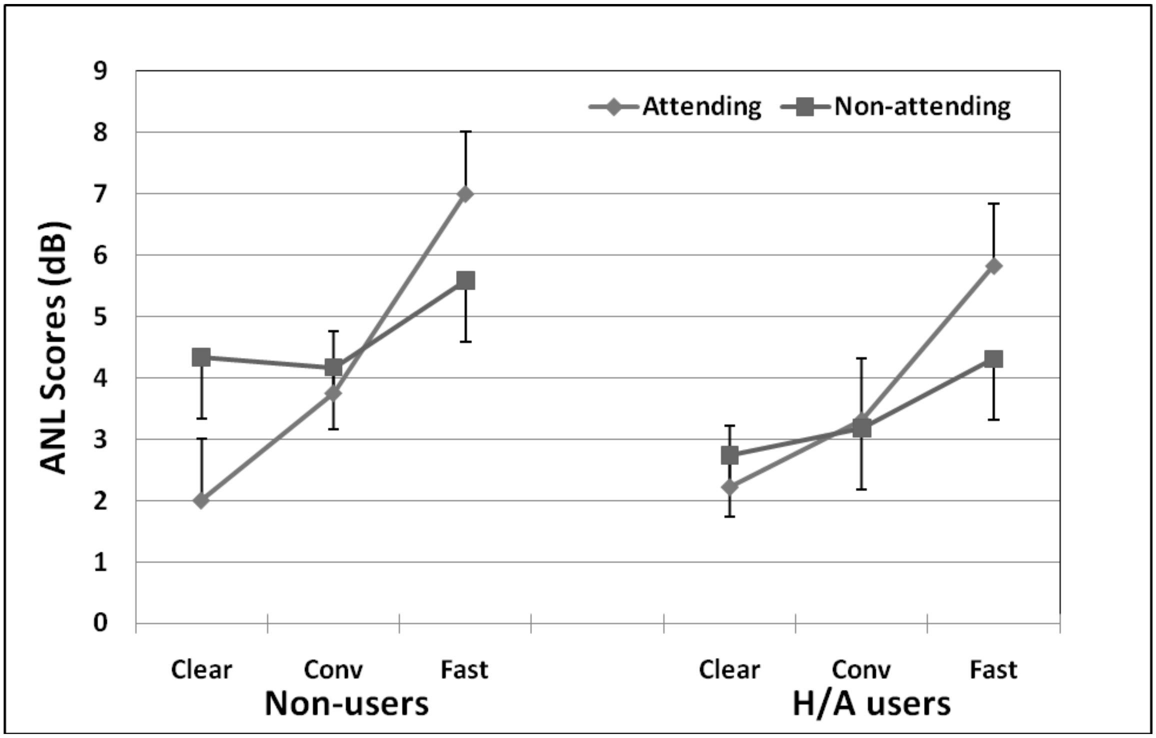

Figure 3: Mean ANL and standard error for the two participant groups of hearing aid users and hearing aid nonusers under conditions of attending and non-attending across the three stimulus types. Low ANL scores represent better tolerance to background noise than high ANL scores.

Although there was not a strong main gender effect, there was a significant interaction (f[2,62]=4.621, p=.013) between sex and stimulus type. As shown in figure 4, females had higher mean ANL scores for all stimulus types under both conditions of attention. ANLs for the fast rate stimulus type in the attending condition were significantly higher for females than males.

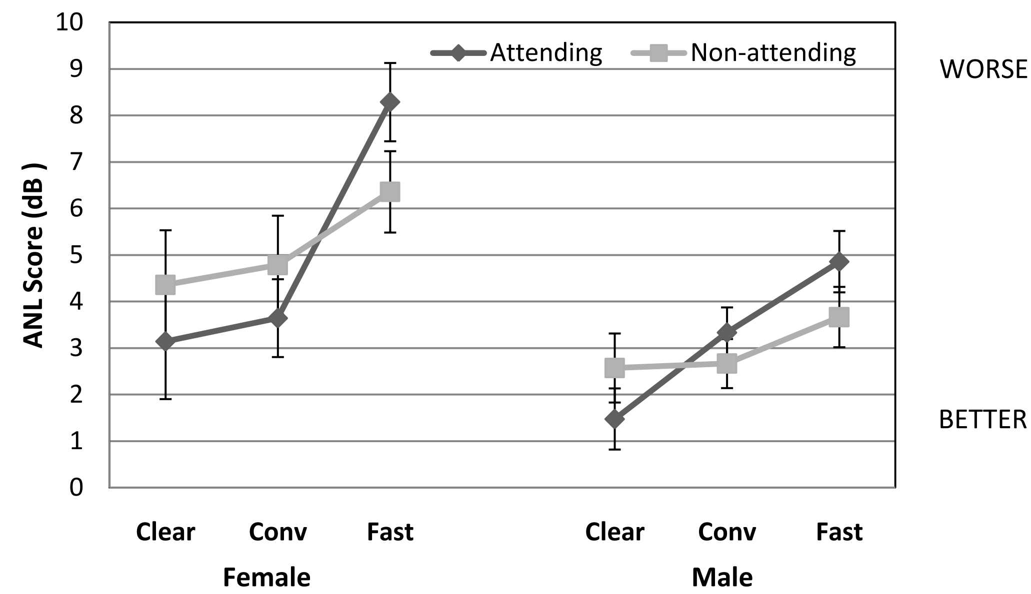

Figure 4: Mean ANL scores for men and women across the three speech stimulus types under conditions of attending and non-attending. Low ANL scores represent better tolerance to background noise than high ANL scores.

One other interaction, between hearing aid use and gender, also reached significance (f{1,31}=5.860, p=.022). However, the hearing aid user group was much larger than the non-hearing aid user group, and the ratio of male to female was different between the two groups. This finding is questionable given the inequality of the samples.

In summary, of the within-subject factors, stimulus type had a significant effect whereas attention did not. A significant interaction for attention vs. stimulus type was also found. Neither between-subject factor of HA-user or sex, reached significance, but significant interactions were found between stimulus type vs. sex and HA-user vs. sex. These results are illustrated in table 1. Pair wise comparisons between stimulus types showed significant differences for clear speech vs. fast-rate speech (α=.05, p=.000) and for conversational vs. fast-rate speech (α=.05, p=.000). The difference between marginal means of clear speech vs. conversational speech reached near significance with a p-value of .053.

Table 1: ANOVA measures for within- subjects (Stimulus type and Attention), between – subjects (HA user and sex) and interactions.

Effect	df	F-value	p-value
Stimulus type* **	**2**	**37.745**	****0.000**
Attention	1	0.154	0.698
Sex	1	0.328	0.571
HA user	1	2.213	0.147
Stimulus type X Attention* **	**2**	**10.874**	****0.000**
Stimulus type x HA user	2	0.919	0.404
Stimulus type x Sex* **	**2**	**4.621**	****0.013**
Attention x HA user	1	1.512	0.228
Attention x Sex	1	0.819	0.372
HA user x Sex* **	**1**	**5.86**	****0.022**

*** = significance reached at $\alpha \leq 0.05$.

Discussion

The results of the present study suggest that for older, hearing impaired listeners, ANL is affected by the intelligibility of the speech stimulus type. For this population, when the speech stimulus was presented with clear speech, individuals were willing to accept a significantly higher level of background noise than when a fast-rate speech signal was presented. When the listener was asked to pay particular attention to the speaker, this difference became even greater, with higher noise tolerance for clear speech and lower noise tolerance for fast-rate speech, when compared to the non-attending condition. In addition, participants in this study had significantly higher ANLs (lower noise tolerance) for fast rate speech as compared to conversational speech in both conditions of attention.

Based on these findings, one could conclude that older, hearing-impaired listeners can tolerate more background noise when listening to speech that is slow and clearly articulated and far less background noise when listening to a very fast speaker. The fact that these results were strengthened under the condition of attention suggests that ANL may also be affected by the listener's perceived importance of understanding the message.

Previous research on ANLs has led to diverse findings on the importance of speech understanding. Nabelek et al, (2006, 2004) found no relationship between ANL and scores on the speech perception in noise test (SPIN). New studies on reverberation, which is known to affect intelligibility, have also resulted in no significant changes in ANL with varying levels of reverberation (Adams et al, 2010).

More recent studies at Starkey Laboratories, Inc. have resulted in significant correlations between participant's ANLs and speech understanding abilities (Reker et al, 2011). According to this study, higher listener concentration and better perceived and actual speech understanding yielded higher noise tolerance (lower ANLs) in both hearing-impaired and normal hearing subjects. Gordon-Hickey and Moore (2008) also found significant changes in ANL with changes in intelligibility of the primary speech stimulus. A previous unpublished study conducted at James Madison University (Goldman, 2009) following an identical procedure with younger, normal-hearing adults, found significant improvement of ANL when clear speech was the stimulus and significantly poorer ANLs when the speech was presented at a fast rate. The results of the present study further support the idea that ANL improves with increased intelligibility of the target speech signal.

Many researchers have concluded that ANL does not vary based on audiometric thresholds (e.g. Nabelek et al, 1991; Crowley & Nabelek, 1996) or age (e.g. Nabelek et al, 2006; Freyaldenhoven & Smiley, 2006; Freyaldenhoven et al, 2007; Adams et al, 2010). Nabelek et al (2006) indicated that ANL may be an inherent characteristic of the individual that does not change with age or acquired hearing loss. This statement is difficult to believe given the commonality of the elderly person's complaint of too much background noise. This difficulty of communicating in the presence of background noise often exceeds what would be expected on the basis of declines in hearing sensitivity (Tun, 1998). A comparison between this study and Goldman (2009) reveals poorer tolerance for background noise exhibited by higher ANLs in the older, hearing-impaired group for all speech stimuli under both conditions of attention.

It is difficult to determine if the reduced noise tolerance of the participants in this study is the result of age or hearing-impairment. The Starkey laboratories research found significantly lower ANLs (better noise tolerance) for the normal hearing group than the hearing-impaired group of similar age (Recker et al, 2011). In a study examining the role of interest level on ANLs (Plyler et al, 2011), authors suggest that the type of speech sample used may affect acceptance of noise in listeners with sensorineural hearing loss differently than listeners with normal hearing. It is possible that hearing-impaired listeners will be more interested in speech that is more intelligible and lose interest in rapid, difficult to understand speech.

Although the older, hearing-impaired group in this study demonstrated higher ANLs, and therefore less noise tolerance, than the younger, normal hearing group studied by Goldman, ANL did not seem dependent on age within the older group. As shown in figure 5, when examining ANL scores in relationship to the individual's age, there does not seem to be any correlation. Figure 2 shows the ANL score from each of the speech signal types in the attending condition. There is a noticeable effect of signal type, with clear speech symbols predominantly in the lower half of the graph and fast rate symbols mostly in the top half of the graph, but there is no trend showing age related differences in ANL for any of the speech signals.

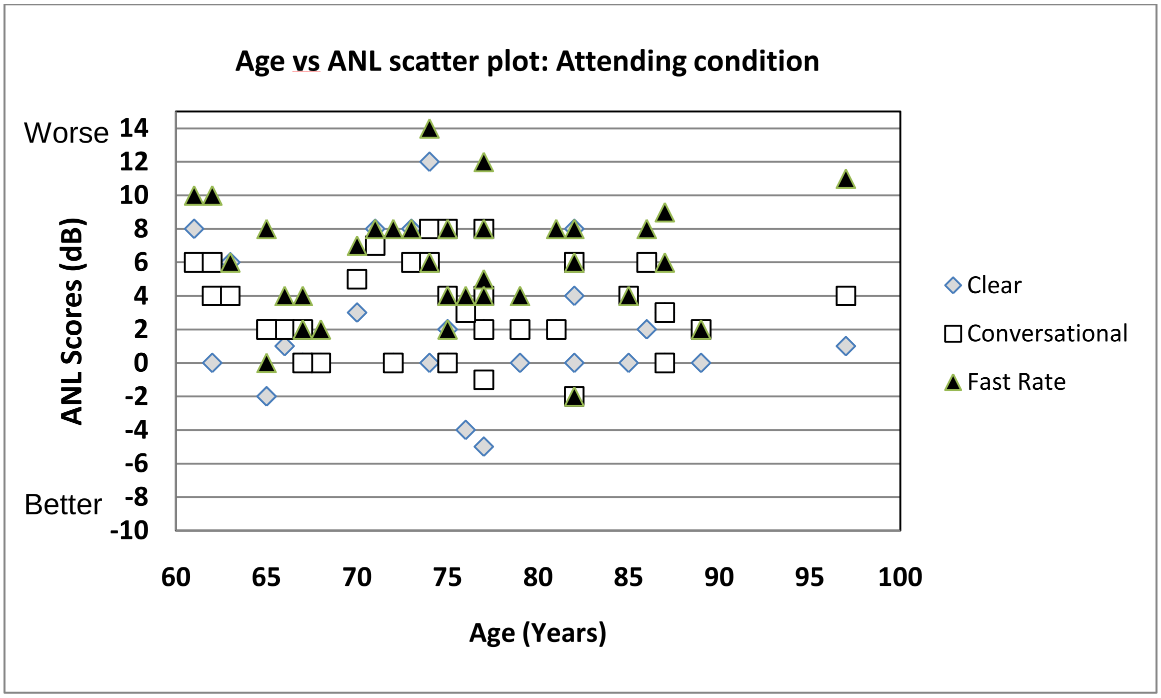

Figure 5: ANL scores recorded from the three different speech signal types (clear, conversational and fast-rate) in the attending condition plotted against the age of the 35 participants.

ANLs from the present study reveal lower ANLs than those recorded by other researchers. Whereas Crowley and Nabelek (2006) report a mean (standard deviation) of 7.6dB (6.5dB); the mean (standard deviation) the mean (standard deviation) ANL of this study was 3.6dB (3.25dB). It is possible that the recruitment method of asking for volunteers from a pool of patients of a hearing aid dispensing office resulted in a bias sample. Perhaps only successful hearing aid users were inclined to volunteer since the unsuccessful users would not likely return for hearing aid checks and cleanings and therefore would not be present to participate. Researchers in the Starkey study also found that their recruitment method biased the results towards lower ANLs with participants being successful hearing aid users and Starkey employees. It would be interesting to compare our results with that of a study of unsuccessful hearing aid users, who in theory should have higher ANLs.

In addition to recruitment bias, several aspects of this study's method may have produced lower than average ANL scores. In the original Nabalek et al studies (1991, 2004, 2006), the participant set the babble noise to their BNL themselves, using a handheld device that raised and lowered the level of noise instead of the clinician controlling the increase in noise level. It is possible that the addition of the tactile stimulation of the device made the participant more aware of the changes in volume, and therefore perceived the noise to be unacceptable at a lower level. Another difference in this study as compared to those found in the literature is the method of approaching the BNL. Nabalek et al used a bracketing approach where the participant set the babble noise in an up-and-down procedure, to an acceptable BNL. This study used an ascending method only, with the participant judging each increase in noise level until it was unacceptable. With less physical participation of the listener and a continuous, gradual increase in noise level, the noise may reach a higher decibel level before the listener notices that it has become unacceptable.

The significant interaction between stimulus type and condition of attention shows that the behavior of carefully attending to an intelligible speech stimulus (clear and conversational speech) improves tolerance to noise in the elderly, hearing –impaired population. Conversely, when the signal is practically unintelligible to the listener (fast-rate), the older, hearing impaired listener appears to give up and have a much lower tolerance for background noise. This interaction was not evident with the young, normal-hearing group.

If intelligibility does affect ANL, then temporal processing deficits associated with aging and hearing loss (Gordon-Salant & Fitzgibbons, 2003) would account for the higher ANL scores recorded for the fast-rate speech stimulus. The young, normal hearing group may not need to be attending more carefully to any of the stimulus types to understand the message, whereas; the elderly, hearing-impaired listener who requires longer processing time, will have to put in considerably more effort as the speech stimuli becomes less intelligible (Larsby et al., 2005). Even when attending carefully, the elderly HI listener may decide that the fast-rate is impossible to understand.

The primary purpose of the present study was to evaluate whether a clear speech stimulus could improve the listener's acceptance of background noise. Goldman (2009) found the clear speech stimulus to yield significantly lower ANLs in younger adults with normal hearing. Although in the present study, the difference between clear and conversational speech stimuli did not reach significance (α=.05, p=.053), there was still a trend of improved ANL with clear vs. conversational speech stimuli. Furthermore, ANLs for both younger and older groups were significantly worse for fast rate speech stimuli, in both conditions of attention.

This study's finding that ANLs were not significantly different for hearing aid users and non-hearing aid users agrees with previous data (Nabelek et al, 2004; 1991) which compared ANLs from aided and unaided hearing impaired listeners. The fact that amplification does not appear to affect ANL supports the original purpose of noise tolerance testing by Nabelek et al, who believed that ANL is inherent to an individual and can be established prior to hearing aid fitting as a predictor of level of success with hearing aid use. However, since the improvement of directional microphones and noise reduction technology, research suggests that ANLs improve approximately 4 dB when the listener is aided and these features are activated (Plyler et al, 2011). Further research should investigate the effect of clear speech on ANLs of hearing-impaired listeners aided with directional, noise reduction hearing aids.

As stated earlier, previous research concluded that ANLs were not dependent on age, gender or hearing sensitivity. The findings from the present study disagree, with differences found between the older, hearing-impaired group and the younger, normal-hearing group. For the two groups in question, ANLs were overall lower in the younger, normal-hearing group. In addition, females in the older, hearing-impaired group had higher ANLs, across all stimulus types and conditions, than males. However, both groups from the research at James Madison University had lower mean ANLs than that found by the researchers at the University of Tennessee.

Most previous ANL research has used conversational speech as the only speech stimulus. Using several different speech stimulus types, this study showed that ANL could increase or decrease depending on the ease of speech understanding. Results indicated that acceptance of background noise was dependent on the type of speech stimulus presented, with clear speech allowing the most tolerance and fast-rate speech resulting in the least tolerance of background noise. In addition, for older, HI individuals, careful attention to a clear or conversational speech stimulus could improve acceptance of noise. Further research in a more clinical setting should be done to investigate the real world benefit of using clear speech when conversing with the elderly and hearing-impaired. Additionally, the act of careful attention to speech as a means of improving acceptance of noise could be explored more thoroughly. If these methods are found to significantly improve speech understanding and acceptance of background noise, they should be included in a comprehensive aural rehabilitation program.

Chapter 2: Extended Review of Literature

In 1977, the Health Interview Survey estimated that only 20% of hearing impaired persons used hearing aids (Ries, 1982). After 27 years of hearing aid research involving digital processing, noise reduction filters and a variety of improved features, a 2004 survey yielded the same results. Of the 31.5 million Americans with hearing loss, only 20% owned hearing aids. Of those hearing aid owners, only about half were satisfied with their hearing aid benefit (Kochkin, 2005). Among the major reasons identified for dissatisfaction with hearing aids were problems with background noise and unpleasantness of loud sounds. These complaints related to the background noise were voiced both by middle aged subjects and by elderly subjects (Nabelek, Tucker & Letowski, 1991). Predicting who will benefit from amplification and increasing the number of satisfied hearing aid users are major goals of audiologists and the hearing aid industry.

In recent years, audiologists have added speech in noise tests, such as SPIN, to measure a patient's ability to communicate in the real world. However, these speech perception scores obtained in background noise do not predict success with hearing aid use. Nabelek et al (1991) hypothesized that the willingness to listen to speech in background noise may be more indicative of successful hearing aid use than understanding of speech in background noise. This idea led to the development of a procedure known as the Acceptable Noise Level (ANL).

The original study by Nabelek et al measured ANLs by asking listeners to first, adjust running speech to their most comfortable listening level (MCL). Then background noise is introduced and listeners are asked to adjust the noise to their maximum acceptable background noise level (BNL), while listening and following the words of a story. The difference between the BNL and the MCL is the ANL (Freyaldenhoven et al, 2007). Results of this study showed that individuals who accept high levels of background noise (with small ANLs) are likely to become successful hearing aid users.

Further study of ANLs demonstrated that ANLs measured before an individual obtains hearing aids may serve as a good prediction as to whether the listener will become a successful hearing aid user (Nabelek et al., 2006). Successful hearing aid users were defined as those patients who wear their hearing aids most of the time. When individual's have very small ANL scores of 7 or less, they are likely to become full time hearing aid wearers, whereas patients scoring high ANLs of 14 or higher are predicted to be unsuccessful hearing aid users, wearing hearing aids minimally, or not at all. When isolating the extreme high and low ANL scores, the ANL predicts hearing aid usage with approximately 85% accuracy (Nabelek et al., 2006).

The original 1991 Nabelek et al. study examined the hearing impaired participant's ANL during presentation of five different noises, multitalker babble, speech spectrum, traffic noise, pneumatic drill noise and music. The results showed that mean ANLs were similar for the different noise stimuli. Although the study involved five different noises, the running speech was always presented in a conversational speech style at the participant's MCL. When using conversational speech as the speech signal, Nabelek et al. found that ANL measurement is reliable over time (Nabelek et al., 2004) and is not affected by the listener's gender (Rogers, Harkrider, Burchfield, & Nabelek, 2003), hearing sensitivity or age.

Until recently, ANL studies have been conducted when speech is presented at MCL. The first data on the acceptance of background noise was done at speech presentation levels that are optimal for speech recognition. Since listening often does not occur at optimal levels, Franklin et al.(2006), studied the relationship between ANL and speech presentation level for listeners with normal hearing. They found that as speech presentation level is increased, the ANL also increases, but at one-fourth the rate of the increase in speech level. In other words, for every 4-dB of increase in speech presentation, a 1-dB increase occurred in the ANL. They found that within this group of listeners with normal hearing, the effect of different presentation levels was greater for the listeners with larger conventional ANLs than in listeners with smaller ANLs (Tampas & Harkrider, 2006). These investigators concluded that ANL is not a single value but a set of values that depends on speech presentation level, and possibly other factors as well.

Freyaldenhoven et al., (2006) hypothesized that the effects of speech presentation level on ANL will be more severe in hearing impaired listeners. Listeners with sensorineural hearing loss (SNHL) typically have loudness recruitment or the abnormal growth of loudness with increased signal presentation (Moore & Glasberg, 1997). Therefore they thought increased speech presentation level would have a more deleterious effect on participants with hearing loss. However, the results of their study showed that the effects of speech presentation level on ANL are not related to the listener's hearing sensitivity. Age of the listener was also investigated and was found to have no relationship with effect of speech presentation on ANL.

Prior to 2008, researchers who investigated ANL have used speech presentations that were intelligible to those with normal hearing. However, this is usually not the case when evaluating individuals with hearing loss. In a study by Gordon-Hickey and Moore (2008), three different speech conditions were used; intelligible, reversed and unfamiliar. The intelligible passage was conversational speech. The reversed speech was the intelligible passage recorded backward, therefore meaningless, but maintaining the long-term average spectral characteristics. The unfamiliar speech consisted of a Chinese passage that was also digitally altered to match the long term spectral aspects as the intelligible discourse (Gordon-Hickey et al.). Analysis of the results of this study suggested that a change in intelligibility of the speech resulted in a significant change in ANL results. The ANLs for the reversed speech condition and the unfamiliar, Chinese speech condition were both significantly greater than for the intelligible speech discourse.

The Gordon-Hickey et al. study was performed on normal hearing individuals. Patients seen clinically for hearing aid assessment frequently have reduced speech understanding and/or aging. This reduction in speech recognition tends to worsen with progression of hearing loss and/or aging. Previous studies have reported no significant difference in ANL for hearing sensitivity or age. However, these studies have been between-subjects designs. Longitudinal studies to track ANL over time and progressive hearing loss should be investigated to see if reduced speech understanding in the elderly results in changes in ANL.

A previous dissertation on ANLs examined the impact of varying degrees of speech intelligibility on the ability to attend to a spoken message in the presence of competing background noise (Goldman, 2009). In this study, the effects of using either Clear Speech, conversational or temporally altered speech, on ANL scores in normal hearing listeners was assessed.

Clear speech is produced by reducing the speaking rate, adding longer pauses between words, voicing longer on vowels and carefully articulating consonants. When analyzed, clear speech has been found to have greater temporal envelope modulations and more energy at higher frequencies (Krause & Braida, 2004). The speaking rate of clear speech is approximately 100 wpm compared to normal conversational speech which ranges between 200-300 wpm. Previous studies have demonstrated that this altered speaking style is significantly more intelligible than conversational speech for hearing-impaired listeners in quiet, noisy and reverberant environments (Picheny et al., 1985).

Learning to use clear speech can be as simple as asking the speaker to speak more clearly. However, training on the clear speech method has shown to produce speech that is more easily recognized and maintained more consistently over time. A study by Caissie et al., (2005), showed that when listening to an untrained talker using clear speech, hearing impaired listeners acquired improved speech recognition scores, but performance was still below that of the normal hearing group. When the clear speech was presented by a trained talker, scores of the impaired hearing group were not significantly different than the normal hearing group. These results emphasize the importance of aural rehabilitation in the clinical setting. If clear speech training was offered to friends and family members of the hearing impaired patient, speech recognition and possibly perceived hearing aid benefit would improve.

Temporally altered speech is often used as a way to investigate age differences in word recognition and speech processing. Presenting speech at a fraction of a normal, conversational speech has been shown to decrease speech understanding in all listeners, but the effect is more pronounced in the hearing impaired and elderly populations. In a study on the effects of rapid speech and background noise, older adults with normal hearing showed an increase in susceptibility to increased speaking rates on a speech recognition and recall (Tun, 1998). Other studies using time compressed speech have shown a greater deficit in understanding and recall, compared to younger adults for both spoken words and sentences (Gordon-Salant & Fitzgibbons, 1993). Researchers suggest that under conditions of background noise and time compressed speech, the listener is presented with degraded sensory input paired with an increase in cognitive load resulting in additional effort to process the speech signal. Age-related difficulties in understanding temporally altered speech could arise as a consequence of temporal processing deficits associated with peripheral hearing loss, central timing issues and cognitive capacities.

In the previous dissertation on ANLs, when establishing the maximum background noise level tolerated (BNL), Goldman presented the background noise in both an ascending and descending approach. Goldman's research resulted in consistently lower scores in the ascending method than the descending approach. However, the ANL scores for both approaches yielded the same overall pattern in all three noise conditions and for the two levels of attention (Goldman, 2009). It is thought that the descending method may artificially produce higher ANLs due to the louder, more distracting, initial level of background noise and a practice effect of repetitious, high levels of noise. Although the difference in approach is interesting, it does not seem clinically relevant. Whether an individual is exposed to background noise that increases gradually, or starts at a maximum level and decreases, cannot be controlled by the listener. Since the two approaches yielded the same trend of results, the present study will use the ascending approach only.

In the dissertation by Goldman (2009) which followed this procedure with normal hearing younger adults, a significant effect for speech stimuli was found. In all conditions, mean ANL scores were lowest for clear speech stimuli and highest for fast rate speech. One would predict similar, if not greater, significant results in the older and hearing impaired population. However, the rationale for an increase in ANL with decreasing levels of intelligibility of the speech signal may be more complex than simple speech recognition.

According to Moore (1996), when the sensory signal from the ear to the brain is limited, due to hearing impairment or due to background noise, the listener has to compensate for the limited signal by means lip-reading and knowledge about language structure and vocabulary in order to comprehend the speech message. To handle this task, the listener has to depend on cognitive ability to interpret and store information and to integrate information with existing knowledge from hearing and vision (Hallren et al., 2001b). Unless a normal hearing individual is in a very noisy environment, their processing of speech is automatic, fast and accurate. When hearing impaired, the task of processing becomes cognitively controlled, demanding longer processing times which demands considerably more effort by the listener (Larsby et al., 2005).

Aging often means not only degradation of peripheral hearing, but also decline in cognitive function. In general, the elderly have a lower performance level on highly demanding working memory tasks as well as a decreased cognitive speed (Li et al., 2001). Previous studies have shown that the elderly are more easily disturbed by competing meaningful messages (Larsby et al., 1995), and find it difficult to focus on what's important and ignore unnecessary and distracting information (Hallgren et al, 2001a). Research conducted at the University of Maryland examined the effect of rate variations in background noise composed of multiple talkers on recognition of rapid speech. The principle findings were that older listeners perform more poorly than young listeners on nearly all speech recognition tasks involving speeded speech and in all noise conditions. These authors attribute the age-related deficit in the ability to ignore background of distracting information to a cognitive decline in executive function.

New studies are beginning to address this inability to ignore unnecessary background noise in the elderly and the hearing impaired. Research relating suppression and speech-in-noise perception, are attempting to explain why older hearing aid users often report that amplification is less effective in noisy environments. Sommers & Gehr (2009), obtained two-tone suppression measures from normal hearing, older and younger adults to determine whether age, independent of hearing loss, affect this measure of cochlear nonlinearity. Their work resulted in two significant findings; age, independent of hearing, impairs auditory suppression and suppression may contribute to listener's ability to understand speech in the presence of background noise. These authors suggest that if speech perception in noisy backgrounds is affected by age-related declines in both absolute sensitivity and auditory suppression, assessments of suppression may provide a more accurate prediction of speech perception in noise for hearing impaired older adults.

The fast rate speech signal offers a challenge in temporal processing in the elderly listener. Grose & Mamo (2010) studied changes in processing of temporal fine structure to explain why older listeners had more difficulty following rapid changes in sound. Results of this study requiring the listener to interaural phase differences, support the notion that deficiencies in some aspects of auditory temporal processing occur in the older adult, and that these changes begin to emerge relatively early in the aging process.

Functional magnetic resonance imaging has shown that activation of the auditory cortex during selective listening to speech decreased in elderly subjects compared to young subjects, especially in noise. Specifically, Hwang et al. (2007), found reduced activation in the anterior and posterior regions of the bilateral superior temporal gyrus, in the elderly during selective listening.

Considering that the present study uses multi-talker babble as the noise source, it is possible that the elderly are distracted by this noise in a different way than the younger, normal hearing group. It may not be the level of noise, as much as the informational masking effect of the competing speech, on the elderly. Although the original study (Nabelek et al., 1991), found no significant differences in results on ANL when using five different types of noise, it is likely that speech babble is more distracting than other noise to the elderly and hearing impaired.

Certainly much of the research, as presented above, confirm the degradation of the speech signal when presented at faster rates, especially for the elderly and hearing impaired. However, since the conversational speech condition is most similar to the speech in multitalker babble, it is possible that the cognitive and neural deficits that prevent the elderly, hearing impaired individual from separating the relevant signal from irrelevant noise, will make the conversational speech condition most challenging and annoying for the participant. Prior research suggests that elderly listeners benefit from temporal modulations in noise compared to steady-state noise when presented with speech in noise tasks. In a study by Gordon-Salant and Fitzgibbons, older individuals showed better recognition of time-compressed sentences when the temporal characteristics of target speech signal and background babble were mismatched than when temporal characteristics were matched (2004). These authors concluded that older listeners compare overall rates of the target and background, and are better able to resolve the target signal when its rate is distinct from that of the speech background. This example of figure-ground separation suggests that overall speech rate relative to background speech rate is a possible cue for improving speech recognition in noise (Gordon-Salant et al., 2004).

In addition to examining speech stimuli, the previous dissertation also investigated the participant's level of attention on ANL scores. Goldman (2009) found that in normal hearing, young individuals, ANL scores are not dependent upon attention of the participant to the target message. Based on the previously reviewed studies, it can be argued that the level of participant attention may significantly affect ANL scores in the elderly hearing impaired. Given that the hearing impaired, elderly individual has more difficulty attending to speech in quiet than the young normal hearing individual, the burden of attending to a difficult speech in noise task will take much more effort and be perceived as much more annoying to the participants in this study.

The previous dissertation by Goldman (2009) determined the impact varying degrees of speech intelligibility have on the ability to attend to a spoken message in the presence of background noise. She found that for younger, normal hearing impaired individuals, background noise was most tolerable when the message was presented with clear speech and least tolerable when the message was presented at a rapid rate. She also found that the level of tolerance to background noise did not change with the participant's state of attention.

Older, hearing impaired listeners often have debilitating communication difficulties in adverse listening environments. Hearing aid manufacturers spend the majority of their research and development resources on technology aimed at providing improved speech understanding in noise and comfort in noise. A study at Vanderbilt University showed a 4.2dB improvement in ANL when the listener's hearing aid employed its digital noise reduction algorithms (Mueller et al, 2006). However, this improvement in the laboratory may not carry over to the real world. The Vanderbilt study used speech-shaped noise instead of speech like noise and the research was conducted in a reverberation-free sound booth. Other researchers have investigated the effect of hearing aid noise reduction and directional microphone technology on ANL. Plyler et al (2011) and Freyaldenhoven et al (2005) also reported improved ANLs with directional microphone technology and noise reduction circuits. However, none of these studies have shown these technologies to produce improved speech understanding in noise.

If a significant improvement in ANL score were found in the clear speech condition, this would be one method of not only improving tolerance to noise, but also speech understanding in noise. Aural rehabilitation that includes counseling to family members , friends and caretakers on the usefulness of clear speech could be a very effective means of improving the patient's understanding of speech as well as their tolerance to background noise. If clear speech is utilized in noisy environments, a newly fitted hearing aid patient may be more accepting of amplification and therefore have a better probability of becoming a successful hearing aid user.

Appendixes

Appendix A: Instructions for Producing clear speech

Clear speech is characterized by overly exaggerated speech sounds produced at a slower speaking rate with longer pauses in between phrases. Another characteristic is adding emphasis or stress on the key words in each sentence. All of the speech sounds within each word are Clearly articulated as compared to conversational speech which often combines or deletes weak syllables found in the final position of a word; for example the word moun<u>tain</u> is often produced as “mountn” which sounds more like one syllable than as two syllables.

The following are a list of example sentences which have been converted to clear speech. The bold faced words are the key words which should be emphasized and the underlined spaces between the phrases represent the pauses to be inserted during production.

- We were **looking ___** for a **white ___ truck** to **buy**.
- **Who ate** the **__ last piece __**of **cake**?
- The **dog** was ___ **waiting __** in the **car.**

Appendix B: Lists of sentences used in each condition

Track 2- 1.5 x rate – Nail & Woodpecker

1. Nails are used to fasten wood together.
2. Pioneers used wooden pegs instead of nails.
3. One end of a nail is quite pointed.
4. This point creates an opening for the nail.
5. It also helps keep the wood from splitting.
6. At the nail's other end is a head.
7. It provides a striking surface for the hammer.
8. It also covers the nail hole in the wood.
9. There is a special nail for every purpose.
10. For most purposes a round nail will do.

1. The woodpecker is a bird with a strong beak.
2. It bores holes in trees looking for insects.
3. Woodpeckers live in all parts of the world.
4. The toes of woodpeckers are very unusual.
5. Two point forward and two face backward.
6. This allows the bird to cling to trees.
7. The tail feathers of a woodpecker are stiff.
8. They can use their tails as a support.
9. They also use their tails to grasp trees.
10. Woodpeckers have a long tongue with pointed tips.

Track 3 1.5x rate- Owl & Vegetable

1. Owls hunt alone at night for food.
2. These birds kill and eat small animals.
3. They are birds of prey, like eagles.
4. Owls defend our gardens by eating mice.
5. They are closely related to night hawks.
6. There are five hundred different kinds of owls.
7. They live throughout cold and tropical climates.
8. Owls usually live alone in the forest.
9. Sometimes they exist on remote sea islands.
10. Owls are known for their solemn expression.

1. The word “vegetable” has several meanings.
2. It is used in the phrase “vegetable kingdom”.
3. This refers to the entire plant world.
4. Some wild vegetables can be eaten.
5. Vegetables come from the leaves and flowers of plants.
6. Some vegetables come from a plant’s roots.
7. Vegetables can be eaten raw or cooked.
8. The best way to cook vegetables is by steaming.
9. They are usually chopped or mashed before eaten.
10. Vegetables are very different from fruits.

Track 4- Clear- Window & Glove

1. **Windows** ___ provide **light** and **air**___ to **rooms.**

2. **Windows** were once__**covered** with __ **crude shutters.**

3. Later ___ **oiled paper** was ___ used for __ **windowpanes.**

4. **Glass** windows___ **first** appeared ___ in ancient **Rome.**
5. **Colored** glass ___ was **used** in ___**European** windows.
6. Some **churches** were ___ **famous** for their ___ **beautiful** windows.
7. These windows **displayed** ___ **pictures** ___ from the **Bible.**

8. **Pieces** of glass ___ were **held** ___ **together** by **lead.**
9. Such **windows**___ **may** be seen__ in **French cathedrals.**
10. **English** churches___ also contain **stained** ___ glass **windows**.

1. **Gloves** are ___**clothing** worn ___ on the **hands.**
2. The **word** "glove" ___ **means** _" **palm** of the hand".
3. **Crude** gloves __ were **worn** ___ by **primitive** man.
4. **Greeks** wore **working** gloves ___ to **protect** their hands.
5. The **Romans** ___ used gloves ___ as a **sign** of **rank**.
6. **Knights** ___ used to **fasten**__ gloves to their **helmets.**
7. The **gloves** showed___ their **devotion** __ to their **ladies.**
8. A glove **thrown** __ on the **ground**__ **signaled** a **challenge.**
9. **Knights** threw them__ at their **enemy's feet**.
10. Fighting **started**__ when the **enemy**_ **picked** up the **glove.**

Track 5- Clear – Umbrella & Giraffe

1. The **name** "umbrella" ___ **means __** small **shadow**.
2. **Umbrellas** were **___** first **used__** in ancient **Egypt.**
3. They **gave __protection__** from the **fierce sunshine**.
4. **Slaves** held**__ umbrellas__ over** their **masters.**
5. In **Egypt** today___ many people **carry __ umbrellas.**
6. In early **Rome___** only **women__ used** umbrellas.
7. If a **man** did**__** he **was __**considered **sissy.**
8. Umbrellas were **used __** by **both sexes___** in **England**.
9. **Today__** people **use** umbrellas **__** to **keep out __** the **rain.**
10. Umbrellas **used ___**as **sunshades__** are called **parasols.**

1. The **giraffe** is___ the **tallest wild animal**.
2. It is **three times__ taller** than a **man.**
3. A **full grown** giraffe**___** is **eighteen feet high**.
4. The **giraffe** has**___** an extremely **long neck**.
5. The **neck** has only **__ seven** neckbones.
6. The giraffe's **body___** is about the **size___** of a **horse's.**
7. The **body** is **___ shaped** like **__** a **triangle.**
8. **Africa__** is the only **country__ where** giraffes **__ live wild**.
9. **Large groups** of them **__** are **found __** on the **plains**.
10. They **live** there**__** with **lions** and**__** **elephants.**
11.

Track 6- Conversational- Lung & Dove

1. The lungs are the organs of breathing.
2. They lie in the center of the chest.
3. The heart lies between the lungs.
4. The two lungs are surrounded by the ribs.
5. Both are joined together by the windpipe.
6. This airway extends from the mouth and nose.
7. The lungs contain several million air cells.
8. Blood is pumped through the lungs by the heart.
9. Oxygen is carried to the cells this way.

1. A dove is a small, trim bird.
2. The best known is the mourning dove.
3. The mourning dove lives in North America.
4. Its name comes from it sad mating call.
5. It is sometimes incorrectly called turtledove.
6. The mourning dove is about a foot long.
7. Its body is brown with gray wings.
8. It feeds on grains, grasses and weeds.
9. The mourning dove is a careless housekeeper.
10. Its nest is just some sticks tossed together.

Track 7- conversational- Carrot & Grass

1. A carrot is a vegetable related to parsley.
2. The long stem of the carrot grows underground.
3. It is this stem that most people eat.
4. The leaves of the carrot are also eaten.
5. They are often used to flavor foods.
6. Spring crops are grown in the western states.
7. The crop is harvested in one hundred days.
8. Fall crops are grown in the northern states.
9. Winter harvests usually come from California.
10. Winter crops are also grown in Texas.

1. Grass can grow in all climates.
2. There are many forms of grasses.
3. Many grasses are important food sources.
4. Some grasses grow higher than a man's head.
5. Among these are bamboo and sugar cane.
6. Other types are only a few inches tall.
7. Some grasses are as slender as threads.
8. Others are stiff enough to stand a heavy snow.
9. Most grasses are flowering plants.
10. These flowers bloom mainly in the spring.

Appendix C: Testing Instructions for Participants

Instructions for establishing Most Comfortable Listening Level (MCL)

You will be listening to my voice as I say a list of words through the loudspeaker in front of you. As I am speaking please select the level at which my voice is most comfortable for you by saying either "up" for an increase in volume or "down" for a decrease in volume. When the level of my voice is at a comfortable listening level for you simply raise your hand. We will repeat this procedure again before continuing to the next task. Do you have any questions regarding the task?

Instructions for establishing Background Noise Level (BNL)

You will be listening to a short paragraph read three different ways in the presence of several other people talking at once in the background. As the story is read please indicate the amount of background noise that you are willing to put up with while listening to the story. We are interested in finding out the maximum amount of background noise you can tolerate before becoming tense or tired trying to follow the story. Simply point up showing you can tolerate more background noise or point down indicating you need less background noise as the story is read. Do you have any questions regarding the task?

We are going to repeat this same procedure, only this time I want you to listen very carefully to the story. I will be asking you questions about each story when the experiment is over. Just as before, please indicate the amount of background noise that you are willing to put up with while listening very carefully to the story.

The above instructions were adapted from the original work of Nabelek et al. 2006 Appendix 2, p.639.

Appendix D: Copy of Consent Form

Consent to Participate in Research

Identification of Investigators & Purpose of Study

You are being asked to participate in a research study conducted by Jennifer S. Mundorff and Dr. Ayasakanta Rout from James Madison University. The purpose of this study is to determine if different types of spoken messages are easier to listen to in the presence of background noise. This study has the potential to impact the way hearing impaired listeners are able to cope with noise and improve communication skills. This study will contribute to the student's completion of her dissertation in order to fulfill the graduation requirement of the Au.D. degree.

Research Procedures

Should you decide to participate in this research study, you will be asked to sign this consent form once all your questions have been answered to your satisfaction. This study consists of several listening tasks and a hearing screening that will be administered to individual participants at The Better Hearing Center, Inc. You will be asked to provide answers to a series of questions related to ease of listening to different types of recorded messages in the presence of background noise.

Time Required

Participation in this study will require 2 hours of your time.

Risks

The investigator does not perceive more than minimal risks from your involvement in this study.

The investigator perceives the following are possible risks arising from your involvement with this study: patient fatigue. The participant will be free to take as many breaks as needed.

Benefits

Potential benefits from participation in this study include a free hearing test and information on the participant's tolerance and distraction level of competing background noise in listening situations.

Confidentiality

The results of this research will be presented at dissertation defense meetings with appropriate JMU Communication Sciences and Disorders faculty members. The results of this project will be coded in such a way that the respondent's identity will not be attached to the final form of this study. The researcher retains the right to use and publish non-identifiable data. While individual responses are confidential, aggregate data will be presented representing averages or generalizations about the responses as a whole. All data will be stored in a secure location accessible only to the researcher. Upon completion of the study, all information that matches up individual respondents with their answers will be destroyed.

Participation & Withdrawal

Your participation is entirely voluntary. You are free to choose not to participate. Should you choose to participate, you can withdraw at any time without consequences of any kind.

Questions about the Study

If you have questions or concerns during the time of your participation in this study, or after its completion or you would like to receive a copy of the final aggregate results of this study, please contact:

Researcher: Jennifer S. Mundorff Advisor: Dr. Ayasakanta Rout Communication Science and Disorders Communication Science and Disorders James Madison University James Madison University

Email Address: mundorjs@dukes.jmu.edu Email Address: routax@jmu.edu

Telephone: 540-293-7946 Telephone: 540-568-3867

Questions about Your Rights as a Research Subject

David Cockley, Ph.D.

Chair, Institutional Review Board

James Madison University

(540) 568-2834

cocklede@jmu.edu

Giving of Consent

I have read this consent form and I understand what is being requested of me as a participant in this study. I freely consent to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

____

Name of Participant (Printed)

______________________________________ ______________

Name of Participant (Signed) Date

Appendix E: Raw Data

				Attending				Non-attending		
Age	Sex	HA user	Subject #	clear	conv	fast		clear	conv	fast
77	f	N	S6	-5	-1	5		7	2	6
67	m	N	S9	0	2	4		-2	0	2
87	m	N	S16	3	3	9		3	3	-1
71	m	N	S19	8	7	8		6	5	6
73	m	N	S28	8	6	8		8	8	6
79	m	N	S29	0	2	4		-2	4	6
62	f	N	S30	6	6	10		2	2	4
63	m	N	S31	6	4	6		8	6	8
74	m	N	S32	0	6	6		8	4	8
75	m	N	S33	0	8	8		4	6	8
72	f	N	S34	0	0	8		8	8	10
65	f	N	S35	-2	2	8		2	2	4
85	m	Y	S1	0	4	4		-2	2	0
66	m	Y	S2	1	2	4		3	3	4
62	m	Y	S3	0	4	10		3	3	6
97	f	Y	S4	1	4	11		4	5	9
65	m	Y	S5	-2	2	0		2	0	4
75	f	Y	S7	2	0	4		2	0	2
70	m	Y	S8	3	5	7		3	3	5
82	m	Y	S10	4	6	6		0	4	4
68	f	Y	S11	0	0	2		0	0	0
77	f	Y	S12	8	8	12		4	4	6
77	m	Y	S13	2	2	4		1	2	2
76	m	Y	S14	-4	3	4		3	1	1
86	f	Y	S15	2	6	8		12	12	8
67	m	Y	S17	0	0	2		2	2	2
74	f	Y	S18	12	8	14		12	12	10
81	f	Y	S20	2	2	8		-2	2	4
82	m	Y	S21	0	-2	-2		-2	-2	-2
61	f	Y	S22	8	6	10		8	6	10
75	m	Y	S23	2	4	2		6	2	4
77	f	Y	S24	2	4	8		2	4	6
87	m	Y	S25	0	0	6		-2	0	4
82	f	Y	S26	8	6	8		0	8	10
89	m	Y	S27	0	2	2		4	0	0

References

Caissie, R., Campbell, M.M., Frenette, W.L., Scott, L., Howell, I., & Roy, A. (2005). Clear speech for adults with a hearing loss: Does intervention with communication partners make a difference. *Journal of the American Academy of Audiology;* 16, 157-171.

Crowley, H.F. & Nabelek, I.V. (1996). Estimation of client assessed hearing aid performance based upon unaided variables. *Journal of Speech and Hearing Research*, 39, 19-27.

Franklin, C.A., Thelin, J.W., Nabelek, A.K., Burchfield, S.B. (2006). The effect of speech perception level on acceptance of background noise in listeners with normal hearing. *Journal of the American Academy of Audiology;* 17, 141-146.

Freyaldenhoven, M.C., Nabalek, A.K., Burchfield, S.B., & Thelin, J.W. (2005). Acceptable noise level as a measure of directional hearing aid benefit. *Journal of the American Academy of Audiology*; 16, 228-236.

Freyaldenhoven, M.C., Pyler, P.N., Thelin, J.W. & Burchfield, S.B. (2006). Acceptance of noise with monaural and binaural amplification. *Journal of the American Academy of Audiology;* 17, 659-666.

Freyaldenhoven, M.C., Smiley, D.F., Muenchen, R.A., Konrad, T.N. (2006.) Acceptable noise level: Reliability measures and comparison to preference for background sounds. *Journal o f the American Academy of Audiology;* 17, 640-648.

Freyaldenhoven, M.C., Plyler, P.N., Thelin, J.W. & Hedrick, M.S. (2007). The effects of speech presentation level on acceptance of noise in listeners with normal and impaired hearing. *Journal of Speech, Language and Hearing Research;* 50, 878-885.

Goldman, J.M. (2009). The effects of testing method, alternative types of target stimuli and attention on acceptable noise level (ANL) scores in normal hearing listeners. *PhD Dissertation at James Madison University.*

Gordon-Hickey, S. & Moore, R.E. (2008). Acceptance of noise with intelligible, reversed, and unfamiliar primary discourse. *Research and Technology;* 10, 6-18.

Gordon-Salant, S. & Fitzgibbons, P.J. (1993). Temporal factors and speech recognition performances in young and elderly listeners. *Journal of Speech and Hearing Research;* 36, 1276-1285.

Grose, J.H. & Mamo, S.K. (2010). Processing of temporal fine structure as a function of age. *Ear and Hearing*; 31, 755-760.

Hallgren M., Larsby, B., Lyxell, B. & Arlinger, S. (2001a). Cognitive effects in dichotic speech testing in elderly persons. *Ear and Hearing*; 22, 120-129.

Hallgren M., Larsby, B., Lyxell, B. & Arlinger, S. (2001b). Evaluation of a cognitive test battery in young and elderly normal-hearing and hearing-impaired subjects. *Journal of the American Academy of Audiology*; 44, 131-143.

Hwang, J.H., Chia-Wei, L., Chang-Wei, W. & Jyh-Horng, C. (2007). Aging effects on the activation of the auditory cortex during binaural listening in white noise: An fMRI study. *Audiology & Neurology;* 12, 285-294.

Kochkin, S. (2002b) Ten year customer satisfaction trends in the US hearing instrument market. *The Hearing Review;* 9, 18-22.

Krause, J.C. & Braida, L.D. (2002.) Investigating alternative forms of clear speech: The effects of speaking rate and speaking mode on intelligibility. *Journal of the Acoustical Society of America;* 112(5), 2165-2172.

Krause, J.C. & Braida, L.D. (2009). Evaluating the role of spectral and envelope characteristics in the intelligibility advantage of clear speech. *Journal of the Acoustical Society of America;* 125, 3346-3357.

Krause, J.C. & Braida, L.D. (2004). Acoustic properties of naturally produced clear speech at normal speaking rate. *Journal of the Acoustical Society of America:* 362-378.

Larsby, B., Hallgren, M. & Bjorn, L. (2008). The interference of different background noises on speech processing in elderly hearing impaired subjects. *International Journal of Audiology;* 47, 83-90.

Moore, B.J. (1996). Perceptual consequences of Cochlear hearing loss and their implications for the design of hearing aids. *Ear and Hearing;* 17, 133-160.

Moore, B.C.J. & Glasberg, B/R. (1997). A model of loudness perception applied to cochlear hearing loss. *Audiological Neuroscience*; 3, 289-311

Mueller, H.G., Weber, J. & Hornsby, B.W.Y. (2006). The effects of digital noise reduction on the acceptance of background noise. *Trends in Amplification*. 10(2), 83-93.

Nabelek, A.K., Freyaldenhoven, M.C., Tampas, J.W., Burchfield, S.B., & Muenchen, R.A. (2006). Acceptable noise level as a predictor of hearing aid use. *Journal o f the American Academy of Audiology* 17, 626-639.

Nabelek, A.K., Tampas, J.W. & Burchfield, S.B. (2004). Comparison of speech perception in background noise in aided and unaided conditions. *Journal of Speech, Language, and Hearing Research;* 47, 1001-1011.

Nabelek, A.K., Tucker, F.M. & Letowski, T.R. (1991). Toleration of background noise: Relationship with patterns of hearing aid use by the elderly persons. *Journal of Speech and Hearing Research;* 34, 679-685.

Picheny, M.A., Durlach, N.I. & Braida, L.D. (1989). Speaking clearly For the hard of hearing III: An attempt to determine the contribution of speaking rate to differences in intelligibility between clear and conversational speech. *Journal of Speech and Hearing Research;* 32, 600-603.

Picheny, M.A., Durlach, N.I. & Braida, L.D. (1985). Speaking clearly for the hard of hearing I: Intelligibility differences between clear and conversational speech. *Journal of Speech and Hearing;* 28, 96-103.

Plyler, P.N., Lynzee, N. A., Rossini, T.P. & Mapes, K.E. (2011). Effects of speech signal content and speaker gender on acceptance of noise in listeners with normal hearing. *International Journal of Audiology;* 50: 243-248.

Recker, K., McKinney, M.F. & Edwards, B. (2011). What can a noise-tolerance questionnaire tell us about ANLs? Poster presented at American Academy of Auidology conference.

Ries, P.W. (1982). Hearing ability of persons by socio-demographic and health characteristics. United States. *Department of Health and Human Services.* Series 10, Number 140, DHS Publication (PHS) 82-1568.

Rogers, D.S., Harkrider, A.W., Burchfield, S.B. & Nabelek, A. K. (2003). The influence of listener's gender on the acceptance of background noise. *The Journal of the Acoustical Society of America;* 14, 374-385.

Sommers, M.S. & Gehr, S.E. (2009). Two-tone auditory suppression in younger and older normal-hearing adults and its relationship to speech perception in noise. Research paper at Washington University in St. Louis.

Tampas, J.W. & Harkrider, A.W. (2006). Auditory evoked potentials in females with high and low acceptance of background noise when listening to speech. *Journal of the Acoustical Society of America;* 199, 1548-1561.

Tun, P.A. (1998). Fast Noisy Speech: Age differences in processing rapid speech with background noise. *Psychology and Aging;* 13, 424-434.